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Source Variation in *Albizia chinensis* (Osbeck) Mer.: Seed and Seedling Characteristics

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Summary

Effect of source (altitude as well as geographic) variation in seed morphological characteristics, germination percentage and various seedling traits among and within 13 seed sources of *Albizia chinensis* were examined. The middle elevation sources showed consistent variation in different seed traits. Manan and Palampur populations had biggest and heaviest seeds among all the sources. Various seedling traits differed significantly among the sources. Higher shoot length was recorded in Augastyamuni and Tuneta (lower altitudinal populations) sources. Significant differences were also found between and among various sources for all the root-shoot attributes. Root length was observed greater in lower and middle altitude sources (Moolgarh and Tallimari) but root biomass was found higher in high altitude sources (Kundhla and Palampur). Significant positive correlations were found

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between some of the seed traits among the sources, which could be an important criterion for early source selection. The sources from lower (centrally situated) elevational range appeared to be the most variable populations, whereas sources from higher (north-west situated) elevational range were least variable phenotypically. The broad sense heritabilities estimated for various seed-seedling traits showed that a considerable portion of genetic variance is additive which suggests the possibility of rapid genetic improvement on almost all the growth characters at early ages through provenance and parent tree selection in this potential agroforestry tree species.

Key words: Albizia chinensis, seed source, variation, seed, germination, seedling, heritability, altitude, correlation.

Introduction

Albizia chinensis (Osbek) Mer, is a large deciduous tree with feathery foliage and large stipules. It occurs chiefly in moist localities throughout the sub Himalayan tract and valleys up to an elevation of about 1200 m from Himachal Pradesh eastwards, through Uttaranchal and also in West Bengal, Assam, Andaman and Nicobar islands in India (TROUP, 1921). *A. chinensis* is excellent for restoration of degraded lands, produces fuel and small timber, its leaves form excellent fodder for cattle, and it also serves as the suitable host for Lac insect. The tree is extensively cultivated in tea gardens for shade and improving the fertility of soil. It is also used for box making especially tea boxes and heavy packing cases; and to a limited extent as planking, dugouts and small turnery articles such as bouts, utensils and cattle bells. The tree exudes a gum from the stem, which is used sometimes for sizing hand made paper. Due to multifarious nature of this species, it has been overexploited throughout the hills for fuel, fodder and timber requirements.

Inspite of its various uses, no efforts for the genetic improvement of this species have been made. Variability studies are the prerequisite for genetic improvement of any tree species under various agro climatic conditions, (SHARMA *et al.,* 1994; VAKSHAYA *et al.,* 1992). Selection of best provenance of desired species for a given site or region is necessary for achieving maximum productivity both in plantation forestry and in agroforestry systems (SUBRAMANIAN *et al.,* 1992). The significance of variation studies and source testing in forest tree improvement has been very well realized (SALAZAR, 1989; ISIK, 1986; MEHTA and SEN, 1995). Source tests in native species are desirable to screen the available variation for higher productivity and future breeding work (BURELY and WOOD, 1976). In this paper we report the results of a source variation study of *Albizia chinensis* collected from different localities (altitudes) in Central and Western Himalaya, India.

Table 1. – Geographical description of seed collection sites.

Source	(District)	State	Altitude (m asl)	Latitude	Longitude
Augastyamuni	(Rudraprayag)	Uttaranchal	850	30° 21’	78° 59’
Tuneta	(Rudraprayag)	Uttaranchal	860	30° 18’	78° 48’
Moolgarh	(Tehri)	Uttaranchal	900	30° 25’	78° 40’
Gorkhal	(Pauri)	Uttaranchal	950	30° 08’	79° 09’
Langasu	(Chamoli)	Uttaranchal	960	30° 19’	79° 18’
Kund	(Rudraprayag)	Uttaranchal	1010	30° 13’	79° 12’
Tallimari	(Almora)	Uttaranchal	1050	29° 45’	79° 25’
Manan	(Almora)	Uttaranchal	1060	29° 27’	79° 28’
Kundhla	(Uttarkashi)	Uttaranchal	1070	30° 39’	78° 21’
Mandi	(Mandi)	Himachal	1100	31° 42’	79° 15’
Joshiara	(Uttarkashi)	Uttaranchal	1120	30° 44’	78° 26’
Palampur	(Kangra)	Himachal	1160	32° 12’	76° 53’
Gopeshwar	(Chamoli)	Uttaranchal	1400	30° 25’	79° 21’

Material and Method

An extensive survey was conducted to screen natural populations of *A. chinensis* in central Himalaya, (Kumaon and Garhwal hills of Uttaranchal) and Himachal Pradesh (a part of Western Himalaya), India. The details of geographical location (collection sites) of various sources of *Albizia chinensis* are given in *Table 1*.

In the selected stands (seed source) of *A. chinensis*, fresh and mature pods were harvested during December 1999 from five phenotypically superior trees, depending upon the availability of the ideotypes (straight bole, less branches, disease free etc.), which were 100 to 300 m apart to avoid narrowing down the variation in samples due to relatedness or inbreeding (ISTA, 1996). The seeds from each site/source were extracted and kept separately with proper identity of the site concern.

Morphological characteristics of randomly extracted seeds (five replicates of 20 seeds each) *i.e.*-seed size, number of seeds/pod (healthy and damaged seeds separately) and seed weight (5 replicates of 100 seeds each) were recorded for each site. Nursery germination and growth studies were conducted in the experimental nursery of the Department (situated in between 30°13’ N latitude and 78°48’ E longitude at an elevation of 530 m asl). For seed germination study, seeds from each site were soaked in distilled water for 24 hours and then surface sterilized with 0.1% $HgCl_2$ thereafter, washed twice with distilled water. Only sunked seeds in 5 replicates (100 seeds each) from each site were sown in poly bags filled with soil, sand and farmyard manure in 3:3:1 ratio during May 2000. The experiment was laid and analyzed under complete randomized block design. Germination counts were recorded daily and expressed as the percentage. Manual irrigation was applied daily till the onset of rains, while weeding was done fortnightly. Germination studies were also carried out under laboratory condition, seeds from each site were soaked in distilled water for 24 hours and then surface sterilized with 0.1% $HgCl_2$ thereafter, washed twice with distilled water before subjected to germination test. Five replicates (20 seeds each) of 100 randomly selected seeds from every source were placed on double layered Whatman No. 1 filter paper moistened with distilled water in petri dishes (9 cm dia.). These petri dishes were placed in seed germinator prefixed at 25 °C ± 1 °C constant temperature regime in completely randomized fashion (our investigation has shown 25 °C as the optimum temperature for seed germination in this species). Filter paper was replaced at weekly interval to avoid fungal contamination on the seeds. Emergence of radicle and plumule was the criteria for germination. Germination was counted daily till the completion of test duration (*i.e.* 28 days) for further analysis.

At the end of one complete year after sowing in the polybags, ten randomly selected seedlings from each replication were uprooted and assessed for seedling height, collar diameter, shoot length, root length, root -shoot and root nodule dry weight (g) (after drying to constant weight in an hot air oven at 80 °C) for 24 hrs.

All the data were subjected to statistical analysis using mean values, ANOVA, Tukey -test (BARTZ, 1988), simple correlation (GUPTA, 1981), heritability and Genetic gain (JOHNSON *et al.,* 1955).

Tukey -test

Tukey- test was calculated as followed by BARTZ (1988).

$$q \leq \frac{\bar{X}_L - \bar{X}_S}{\sqrt{\frac{MS_{WG}}{N_G}}}$$

Where X_L is the larger of the two means, X_S is the smaller of the two means, MS_{WG} is the MS (error), N_G is the number of replications, q = q (α; κ; DF) with α = significance level, κ = number of populations (of means) and DF = df of error form in ANOVA.

Broad sense heritability (h^2)

Broad sense heritability is the ratio of genetic variance to the total phenotypic variance and was estimated as suggested by JOHNSON *et al.,* (1955).

$$h^2 = \frac{Vg}{Vp}$$

Where, h^2 = Broad sense heritability character
Vg = Genetic variance
Vp = Phenotypic variance

Genetic Gain

Genetic gain is expressed in percentage. It was calculated using the formula given by JOHNSON *et. al.,* (1955).

$$\text{Genetic gain} = \frac{GA}{\bar{X}} \times 100$$

Where, GA = Genetic advance
$\bar{X}$ = Mean of the character

Table 3a. – Variation in seed germination and survival among the sources of *A. chinensis* (values in parenthesis are coefficient of variation).

Provenance	Altitude (m)	Lab Ger. (%)	Nursery Ger. (%)	Survival (%)	Plantable seedlings (%)
Augastyamuni	850	27^{c} (45)	43.66^{b} (38)	79.01^{e} (03)	68.28^{cd} (10)
Tuneta	860	42^{ac} (61)	28.80^{cd} (15)	78.09^{e} (05)	65.4^{d} (06)
Moolgarh	900	48^{ab} (43)	46.86^{b} (30)	82.33^{de} (06)	66.52^{d} (12)
Gorkhal	950	49^{ab} (43)	43.71^{b} (29)	92.08^{a} (07)	82.7^{a} (05)
Langasu	960	53^{ab} . (16)	40.93^{b} (47)	88.43^{ac} (06)	79.28^{ab} (10)
Kund	1010	48^{ab} (38)	24.66^{d} (21)	87.62^{ac} (04)	75.86^{ab} (09)
Tallimari	1050	49^{ab} (21)	19.40^{d} (50)	91.01^{ab} (08)	80.4^{a} (07)
Manan	1060	54^{ab} (24)	38.60^{bc} (36)	88.45^{ac} (03)	72.6^{bd} (15)
Kundhla	1070	45^{ab} (38)	20.40^{d} (27)	86.99^{bcd} (15)	75.4^{bc} (11)
Mandi	1100	38^{bc} (23)	50.00^{b} (11)	84.49^{cd} (09)	66.88^{d} (09)
Joshiara	1120	56.0^{a} (26)	72.74^{a} (27)	70.52^{f} (08)	54.8^{e} (22)
Palampur	1160	47^{ab} (36)	20.60^{d} (16)	79.30^{e} (08)	67.4^{d} (20)
Gopeshwar	1400	46^{ab} (22)	62.00^{a} (41)	89.23^{ac} (06)	78.26^{ab} (10)
Mean		**46.31**	**39.41**	**84.43**	**71.83**

Means followed by the same letter are not significantly (P = 0.05) different.

Result

Significant (P = 0.05) variations were observed for all the seed morphological characters among different sources. The seed traits like seed length, width, thickness and weight varied widely among sources. Seed length varied from 5.6 mm (Kund) to 6.53 mm (Manan); seed width from 4.19 mm (Kund) to 5.08 mm (Palampur) and the seed thickness from 1.05 mm (Kund)) to 1.59 mm (Mandi) (*Table 2*). The greatest seed weight (2.66 g/100 seeds) was recorded in Manan and the least (1.66 g/100 seeds) in Langasu population (*Table 2*).

Highest number of healthy seeds/pod (84.54%) was found in Tallimari, which was closely followed by Gorkhal (82.20%) population and lowest value (69.83%) was found in Manan population. As far as number of damaged seeds/pod is concerned, (to assess the insect / disease incidence) the greatest value (31.29%) was observed in Mandi with lowest mark in Augastyamuni (4.74%) population (*Table 2*). (This value was calculated on percent basis because the total number of seeds/pod was not constant in each population).

Table 2. – Variation in different seed characteristics among the sources of *A. chinensis* (values in parenthesis are coefficient of variation).

Provenance	Altitude (m)	Seed length (mm)	Seed width (mm)	Seed thickness (mm)	Seed weight (g)	Healthy seeds/pod	Damaged seeds/pod
Augastyamuni	850	6.13^{ad} (10)	4.50^{bc} (05)	1.31^{fg} (10)	2.38^{c} (38)	6.83^{ce} (18)	0.97^{ef} (34)
Tuneta	860	6.22^{ad} (03)	4.28^{cd} (02)	1.34^{ef} (04)	2.40^{bc} (06)	7.51^{ac} (09)	1.36^{bce} (18)
Moolgarh	900	5.77^{de} (10)	4.42^{bcd} (05)	1.33^{efg} (05)	2.13^{cd} (10)	7.26^{bc} (15)	0.50^{f} (77)
Gorkhal	950	6.23^{ad} (02)	4.61^{b} (02)	1.45^{bcd} (11)	2.51^{bc} (07)	7.53^{ac} (07)	1.63^{abce} (17)
Langasu	960	5.88^{cde} (07)	4.35^{bcd} (05)	1.24^{g} (02)	1.55^{e} (34)	4.03^{g} (34)	1.99^{abcd} (43)
Kund	1010	5.44^{e} (06)	4.22^{d} (09)	1.07^{h} (08)	1.82^{de} (13)	8.53^{a} (13)	1.13^{def} (32)
Tallimari	1050	6.39^{ab} (06)	4.52^{bc} (07)	1.36^{def} (04)	2.28^{c} (11)	8.19^{ab} (13)	1.31^{bcef} (55)
Manan	1060	6.47^{a} (03)	4.93^{a} (04)	1.42^{cde} (05)	2.80^{ab} (21)	5.77^{ef} (16)	1.29^{cef} (40)
Kundhla	1070	5.94^{bd} (15)	4.37^{bcd} (07)	1.35^{ef} (03)	2.12^{cd} (18)	6.95^{cd} (33)	1.1^{def} (51)
Mandi	1100	5.99^{bd} (04)	4.60^{b} (01)	1.54^{ab} (06)	2.20^{cd} (32)	4.84^{fg} (20)	2.2^{ab} (44)
Joshiara	1120	6.25^{abc} (05)	4.51^{bc} (06)	1.48^{abc} (07)	3.02^{a} (31)	7.72^{ac} (11)	1.01^{ef} (35)
Palampur	1160	6.51^{a} (09)	4.91^{a} (08)	1.56^{a} (15)	1.80^{de} (14)	6.10^{de} (32)	2.04^{abc} (46)
Gopeshwar	1400	6.15^{ad} (04)	4.60^{b} (04)	1.49^{abc} (06)	2.40^{bc} (25)	6.73^{ce} (09)	2.43^{a} (33)
Mean		**6.11**	**4.52**	**1.38**	**2.26**	**6.77**	**1.35**

Means followed by the same letter are not significantly (P = 0.05) different.

Final germination of seed sown under laboratory condition was recorded after 28 days. Maximum value (56%) was found in Joshiara source, and the minimum germination (27%) was occurred in Augastyamuni and Mandi sources. Whereas, the average germination 45.77 percent for all the sources. As far as germination in nursery is concerned, significant differences were found among all the sources. Maximum (72.86%) germination percent was recorded in Joshiara population while it was found minimum (20.60%) in Palampur population. Average value for all the sources was 43.0 percent (*Table 3a*).

The growth traits of seedlings (i.e. shoot length, collar diameter, root length and number of root nodules) were recorded after 12 months of seedling growth in nursery. Maximum (103.83 cm) shoot length was found in Manan and minimum (65.75 cm) in Gopeshwar population. Highest average (12.2 mm.) collar diameter was recorded in Kund and the lowest (5.04 mm) in the seedlings of Joshiara source. Root length varied from 23.71 mm (Langasu) to 35.20 mm (Tallimari) after 12 months growth (*Table 3b*). Values for average number of root nodules ranged from 5.20 (Tuneta) to 18.46 (Mandi) among all the sources, which indicate wide variation among all the sources for this trait (*Table 3b*).

Data for root-shoot biomass revealed significant differences between all the sources. Shoot biomass also differed significantly among the sources, which varied between 2.28 g (Langasu) to 6.36 g (Augastyamuni). Root biomass ranged from 1.20 g (Gopeshwar) to 5.17 g (Palampur), while the average value for all the sources was 3.43 g. As far as root/shoot biomass is concerned, it ranged from 0.35 g (Gopeshwar) to 1.16 g (Kundhla) among all the sources (*Table 3b*).

Correlation-coefficients (r): Correlation-coefficients were computed between and among different seed and seedling parameters. Highly positively significant (P = 0.01) relationships were recorded between seed length-seed width; seed length- seed thickness; seed length-seed weight; seed width-seed thickness. And significant (P = 0.05) but negative correlation was found between laboratory germination percent and number of root nodules per plant. Positive and significant correlation (P = 0.05) was observed between seed weight and nursery germination percent and percent plantable seedling with number of leaves per plant. Relationships between other traits were found non-significant (*Table 4a*). Correlations between all the seed-seedling traits and three geographic variables were also computed. Altitude has significant and positive relationship with seed weight (P = 0.01) and number of leaves per plant (P = 0.05). Latitude was significantly – positively correlated with seed thickness (P = 0.01) and nursery germination percent (P = 0.05). Longitude of the sources had highly significant (P = 0.01) and positive correlation with seed width and thickness (Table 4b).

Coefficient of variation (C.V.): C.V. for various seed and seedling characters showed significant differences among populations (parenthesis values in *Table 2* and *3*). It revealed clearly that all the populations do not have similar level of variation for a given character. Among the 18 characters, laboratory as well as nursery germination was found most variable while all the seed traits along with survival percent, percent plantable seedlings and shoot length were least variable characters among all the sources.

The degree of similarity and dissimilarity of C.V. among the provenances for a given character is also depicted in *Table 2* and *3*. For instance, there was only nine percent difference between the lowest and the highest C.V. for seed weight, whereas the difference was 72 percent for root dry weight.

Table 3b. – Variation in different seedling characteristics among the sources of *A. chinensis* (values in parenthesis are coefficient of variation).

Provenance	Altitude (m)	Shoot length (cm)	Root length (cm)	R/S length	Collar diameter	Leaves/ plant	Shoot dry weight (g)	Root dry weight (g)	R/S dry weight	Leaf dry weight (g)	Root nodules/plant
Augastyamuni	850	97.0 ab (09)	33.8 a (56)	0.33 a (55)	7.56 a (33)	10.2 de (17)	3.96 ac (86)	3.97 ab (86)	1.0 ac (0.5)	1.72 a (31)	13.41 b (25)
Tuneta	860	95.6 ac (19)	27.6 a (23)	0.30 a (30)	6.20 ce (12)	10.1 e (28)	3.81 ac (62)	2.14 de (52)	0.60 ef (44)	0.86 d (63)	5.20 f (63)
Moolgarh	900	89.5 ce (16)	32.8 a (22)	0.39 a (39)	6.22 cd (12)	11.6 cde (13)	3.60 bc (27)	2.80 bde (30)	0.83 bce (36)	1.18 bc (16)	8.62 de (23)
Gorkhal	950	80.0 ef (04)	31.6 a (62)	0.42 a (72)	5.38 f (15)	13.6 b (08)	3.72 ac (34)	2.95 ad (57)	0.92 ac (41)	1.37 b (31)	10.22 cd (12)
Langasu	960	70.76 fg (10)	32.2 a (13)	0.46 a (17)	5.82 def (14)	10.5 de (22)	2.10 d (24)	1.69 e (33)	0.83 bce (31)	0.80 d (19)	14.83 b (19)
Kund	1010	85.6 de (06)	32.8 a (43)	0.40 a (41)	6.68 bc (10)	12.2 bde (16)	4.28 ab (34)	3.52 abc (45)	0.87 bce (55)	0.91 cd (11)	17.02 a (09)
Tallimari	1050	84.7 de (11)	35.2 a (39)	0.42 a (42)	7.15 ab (10)	16.0 a (31)	4.14 ab (24)	2.53 cde (24)	0.64 def (45)	0.94 cd (38)	9.29 cd (16)
Manan	1060	103.8 a (14)	29.4 a (21)	0.29 a (23)	6.54 bcd (10)	13.4 b (33)	5.19 a (49)	3.47 abc (36)	0.81 ce (64)	1.05 cd (34)	8.52 de (29)
Kundhla	1070	91.0 bcd (09)	27.1 a (23)	0.30 a (18)	6.85 ac (08)	13.1 bc (07)	3.71 ac (14)	4.09 a (44)	1.16 a (48)	0.81 d (16)	8.60 de (24)
Mandi	1100	71.8 fg (13)	32.6 a (13)	0.46 a (17)	5.40 ef (07)	12.4 bd (26)	2.53 cd (17)	2.03 de (19)	0.80 ce (14)	1.30 b (31)	18.39 a (14)
Joshiara	1120	86.92 ce (11)	25.8 a (22)	0.29 a (13)	5.23 f (21)	10.0 e (15)	2.58 cd (44)	2.52 cde (14)	1.10 ab (37)	0.99 cd (11)	7.20 e (15)
Palampur	1160	89.6 ce (21)	35.2 a (38)	0.44 a (67)	6.78 ac (06)	14.3 ab (15)	4.76 ab (30)	2.18 de (34)	0.50 f (41)	0.82 d (32)	7.31 e (21)
Gopeshwar	1400	65.5 g (04)	25.6 a (36)	0.39 a (38)	5.16 f (02)	14.0 ab (11)	3.40 bcd (71)	2.58 cde (35)	0.88 bcd (27)	1.91 a (23)	10.51 c (16)
Mean		**85.52**	**30.88**	**0.38**	**6.23**	**12.42**	**3.68**	**2.81**	**1.80**	**1.13**	**10.70**

Means followed by the same letter are not significantly (P = 0.05) different.

Table 4a. – Correlation coefficient between and among the various traits of *A. chinensis.*

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13
2	0.73**												
3	0.78**	0.74**											
4	0.67**	0.32	0.42										
5	-0.10	0.05	-0.15	-0.09									
6	0.26	0.25	0.35	0.62*	0.10								
7	-0.35	-0.09	-0.34	-0.12	0.07	0.42							
8	-0.09	-0.22	-0.26	-0.11	0.09	-0.41	0.02						
9	0.17	0.14	-0.26	0.20	0.06	-0.18	-0.15	-0.33					
10	0.06	-0.01	-0.19	-0.02	-0.06	-0.48	-0.04	0.50	0.34				
11	0.51	0.39	0.33	0.12	0.04	-0.38	-0.27	0.57*	-0.13	0.35			
12	0.11	0.14	-0.05	-0.09	-0.38	-0.48	-0.05	-0.04	0.37	0.42	0.40		
13	0.15	0.17	-0.02	0.01	0.15	0.01	0.37	0.16	0.07	0.46	0.29	0.49	
14	-0.36	-0.27	-0.26	-0.31	-0.53*	-0.08	0.27	0.24	-0.42	-0.10	-0.13	0.06	0.13

Table 4b. – Correlation coefficient between different seed and seedling parameters and three geographical variables.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Altitude	0.38	-0.31	-0.16	0.67**	0.05	0.35	-0.12	0.09	-0.18	-0.04	0.57*	0.37	0.46	-0.13
Latitude	-0.12	-0.01	0.78**	0.32	-0.15	0.62*	0.07	-0.41	-0.15	0.50	-0.13	0.42	0.29	0.06
Longitude	0.06	0.73**	0.74**	0.42	-0.09	0.10	0.42	0.02	-0.33	0.34	0.35	0.40	0.49	0.13

* Significant at P = 0.05, **Significant at P = 0.01

Abbreviations: 1. Seed length; 2. Seed width; 3. Seed Thickness; 4. Seed weight; 5. Lab. Germination; 6. Nursery germination; 7. Nursery survival; 8. Percent plantable seedling; 9. Plant height; 10. Collar diameter; 11. No. of leaves/plant; 12. Root length; 13. Seedling biomass and 14. No. of root nodule.

Table 5. – Estimates of Broad sense heritability (h^2) and Genetic gain for various seed and seedling characteristics in *A. chinensis*.

Estimates	Seed length	Seed width	Seed thicknes:	Seed weight	Survival %	Shoot length	Root length	Collar Diameter	No. of nodule	No. of leaf/plant	Leaf dry wt.	Shoot dry wt.	Root dry wt.	R/S dry wt.	R/S length ratio
Heritability (h^2)	0.120	0.199	0.492	0.403	0.470	0.500	0.120	0.034	0.802	0.265	0.580	0.093	0.071	0.014	0.071
Genetic gain	2.07	4.39	12.96	14.60	0.08	0.17	0.08	0.12	0.80	0.13	0.21	0.09	7.82	0.004	0.06

Table 6. – Analysis of variance for various seed and seedling characteristics among and within the provenances of *A. chinensis*.

		Mean Squares of seed and seedling characters								
Source of variation	DF	PGL	SP	PGN	PPS	SL	RL	NOL	NRN	CD
Population	12	283.65^{NS}	194.87**	1364.16**	305.97**	612.53**	58.93^{NS}	17.60**	80.52**	3.04**
Families	4	321.73^{NS}	18.34^{NS}	186.76^{NS}	38.44^{NS}	499.96**	132.65^{NS}	13.33^{NS}	15.5 **	0.88^{NS}

* Significant at (P = 0.05) and
** Significant at (P = 0.01)

Abbreviations: PGL = Percent germination in laboratory, SP= Survival percent, PGN= Percent germination in nursery, PPS= Percent plantable seedlings, SL= Shoot length, RL= Root length, NOL= Number of leaves/plant, NRN= Number of root nodules/plant, CD= Collar diameter.

Therefore, the variability in seed weight was the most homogenous and the variability in root dry weight was most heterogeneous among the provenances.

Heritability (h^2) broad sense: Among the various seed and seedling traits, broad sense heritability (h^2) was calculated highest (0.802) for number of root nodules followed by leaf dry weight (0.577) and shoot length (0.500) whereas, the least values were recorded (0.136) in R/S dry weight ratio followed by collar diameter (0.341). On the other hand higher genetic gain was achieved by seed weight (14.6%) followed by seed thickness (12.96%) while it was found lowest (0.004%) for R/S dry weight (*Table 5*).

Analysis of variance: Variance analysis between and among the sources for different characteristics revealed highly significant (P = 0.01) variations among the sources (except for laboratory germination and root length), however, these all traits were not significantly different among the families within the source (except for shoot length and number of root nodules per plant) (*Table 6*).

Discussion and Conclusions

A. chinensis populations in central and western Himalaya vary genetically for 18 seed and seedling characters. Variation in six characters was related to geographical variables (altitude, latitude and longitude) associated with origin of the parent trees. Altitude did not affect seed germination in this species. However, seed weight was positively correlated with altitude indicating heavier seeds at higher elevations in this species. Field germination was positively correlated with latitude suggesting higher germination towards northern (colder sites) sources (Mandi, Gopeshwar and Joshiara).

The pattern of variation exhibited by various characters was substantially different at different levels. The ratios of variance components, germination and seedling growth characters showed greatest variation among the populations. The presence of such differences among populations has probably been produced by different intensities of natural selection acting upon these traits in their natural habitats.

Significant correlations between seed weight and nursery germination (0.62) suggested that seeds allocate much of their energies for seed germination; therefore heavier seeds in *A. chinensis* tend to higher nursery germination.

In this study, almost all the seed and seedling characteristics delineated consistent (significant) differences among the sources from different locations and this might reflect the true genetic variation among these sources. This is also indicated

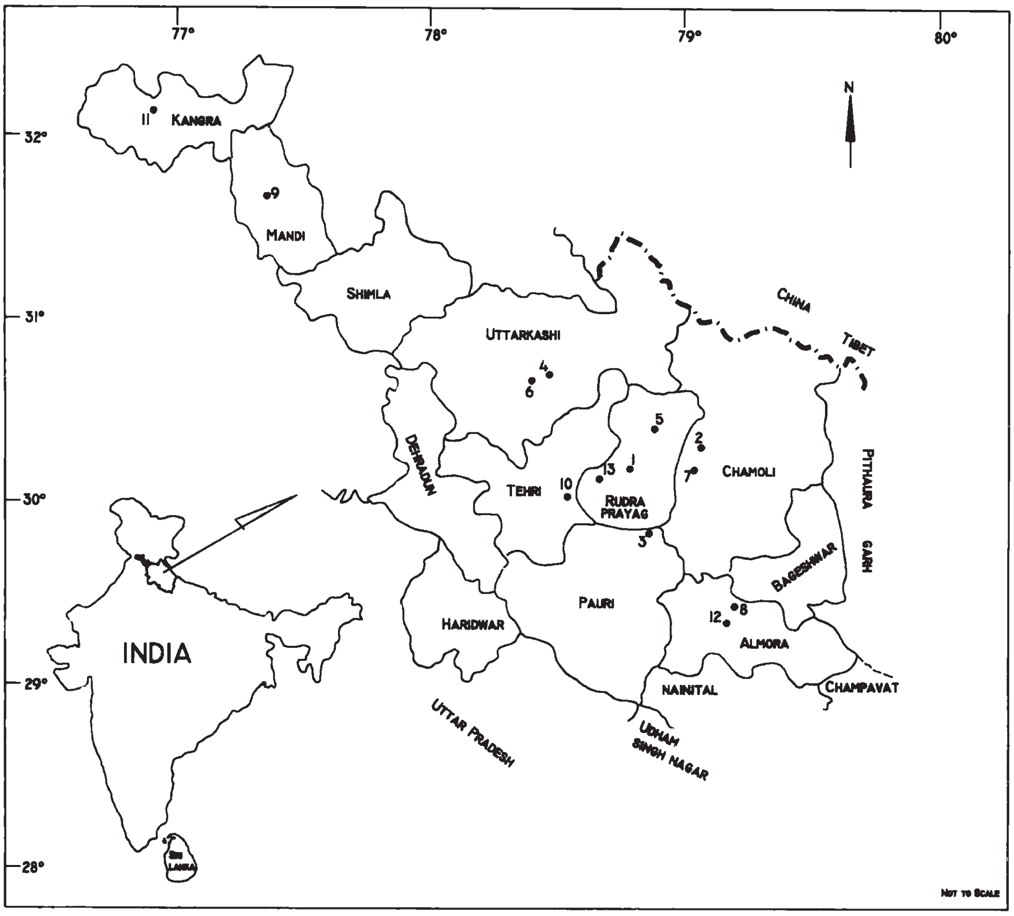

Figure 1. – Seed collection sites (provenances) of *Albizia chinensis:* 1. Augastyamuni, 2. Gopeshwar, 3. Gorkhal, 4. Joshiara, 5. Kund, 6. Kundhla, 7. Langasu, 8. Manan, 9. Mandi, 10.Moolgarh, 11. Palampur, 12. Tallimari, 13. Tuneta.

from the results of analysis of variance for various characteristics (*Table 6*).

The observations incorporated in this paper bring the fact that; seeds of *A. chinensis* collected from 13 sources show large variation in seed morphology, seed weight, seed germination and seedling parameters (*Table 2* and *3*). The differences might have arisen due to the fact that genotypes grew under different environmental conditions in Central and Western Indian Himalaya. Experiments were conducted under similar environmental conditions and they received similar treatments, however, the effect of environment can not be ruled out.

Generally, populations having heavy seeds (Manan and Joshiara) also recorded higher germination percent (*Figure 2*).

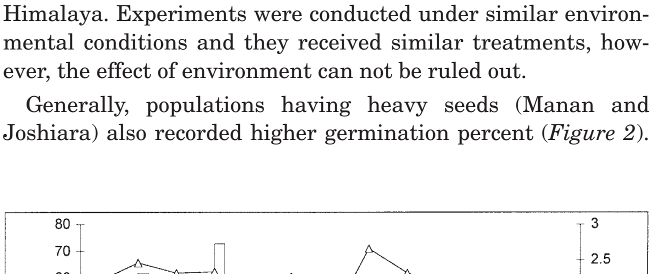

Figure 2. – Variation in seed weight, laboratory and nursery germination percent in seeds from various sources of *A. chinensis.*

Similarly Manan and Joshiara populations also recorded higher average value for seed length and width. These relationships were expected because of interdependence of these characters, which is also clear from correlations computed between different traits (*Table 4a*). Germination percent in nursery is significantly correlated with seed weight (P = 0.05) and seed weight is significantly correlated with seed length (P = 0.01) (*Table 4a*). Highly significant and positive correlations between and among all the traits confirmed their dependence on each other. Larger sized seeds always have heavier seeds in this case, which positively enhanced the nursery germination.

A basic knowledge about the nature and extent of source variation in relation to seed parameters such as germination, seed vigour, seedling characteristics will be very useful for the production of quality seedlings. It has been amply demonstrated that, seeds of a single species when collected from different sources or from different altitudes, differ in viability, germination, growth and biomass performance (Isik, 1986; Todaria and Negi, 1995; Chauhan *et al.,* 1996).

Variations in seed and seedling traits among and within sources suggest that selection among sources might result in rapid genetic gain for the traits (Dangasuk *et al.,* 1997). A significant source variation in pod and seed characteristics has earlier been reported in *Tecomella undulata* (Arya *et al.,* 1993) and *Cassia auriculata* (Sekaran *et al.,* 1997).

It is also revealed from the correlation studies that heavier seeds were found at higher altitudes, it may be due to resource availability (Murali and Sukumar, 1994). It could be result of differences in the environmental conditions, e.g. nutrients, light, or water to which the mother plants were subjected during growing season (WOLFE, 1995).

Seed thickness revealed north – eastern trend, and seed width and thickness were found increasing towards eastern extremes, however, significant relationships were not found between seedling growth parameters and three geographical variables in this case (*Table 4b*). Significant correlation was found between seed weight and seedling growth in *A. nilotica* (GINWAL *et al.,* 1996) and this was considered to be an important trait for early selection of sources.

The degree of variability within each source was different for a given character. It was observed that lower elevational sources (centrally situated) had maximum traits with greater variability while higher elevational (west – north situated) sources had few traits with greater variability. Some of these are higher elevational sources and somewhat isolated from the others. The lower altitudinal sources are centrally located within the optimum range of species natural distribution. Theoretically, these sources receive gene through migration from all directions (ISIK, 1986; SOULE, 1973).

Out of 18 characters, 2–5 (laboratory germination, shoot dry weight, leaf dry weight, root/shoot length, root dry weight) were found most variable in Tuneta, Augutsyamuni, Moolgarh, Gorkhal, and Langasu (lower elevational) sources, whereas only 1–2 (shoot dry weight, root/shoot length ratio) characters were found most variable in Joshiara, Palampur, and Gopeshwar (higher elevational) sources. It indicated that populations from lower altitudes were the most variable, whereas those from higher altitude were the least variable phenotypically. This is contradictory to the findings of ISIK (1986) in *P. brutia* where higher elevational sources were found most variable.

Higher values for broad sense heritability were estimated for number of root nodules/plant, leaf dry weight, shoot length and survival percentage revealing strong genetic control over these traits whereas, R/S dry weight ratio showed least value indicating local environmental as well edaphically control over it. Higher genetic gain was achieved by seed weight and seed thickness, indicating better chances of improving these traits as compared to others.

Although, heritability in broad sense may give useful indication about the relative value of selection in the material at hand, VOLKER *et al.* (1990), SINGH *et al.,* (1993) and GERA *et al.* (1999) have shown that heritability estimates along with genetic gain are more useful than the heritability alone in predicting the resultant effect for selecting the best genotypes for a given trait. Therefore, to arrive at a more satisfactory conclusion, heritability and expected genetic gain should be considered jointly. Moderately high heritability estimates associated with moderate genetic advance have earlier been reported for plant height by SRIVASTAVA *et al.* (1993) in *Terminalia arjuna* and for plant height and stem diameter in *Grewia optiva* by SHARMA and SHARMA (1995), for plant height and stem diameter in *Eucalyptus grandis* by SUBRAMANIAN *et al.* (1995).

Thus variation in *A. chinensis* seed and seedling traits could be due to the fact that this species grows over a wide range of rainfall, temperature and soil types. These populations could have experienced differential selection pressures. Such variation in relation to habitat has also been reported in *A. lebbek* (KUMAR and TOKY, 1993), *A. mangium* (SALAZER, 1989) and *Picea glauca* (KHALIL, 1986). The significant variation in seedling traits within some sources could be due to genetic differentiation resulting from minor environmental differences among the habitat occupied by these sources. Alternatively, it might be attributed to individual tree differences within the sources from which the seeds were collected. Individual trees often vary greatly from one another even when growing in the same stand (ZOBEL and TALBERT, 1984). The morphological characters of seedling height and crown characteristics are known to be strongly inherited (SHIV KUMAR and BANERJEE, 1986). In this study different seedling traits and other traits like seed weight, collar diameter, root length, seedling biomass showed great variation among and within populations, however any single character could not perfectly differ within entire sources. Therefore, all these characters should be considered as important traits for the selection because seedlings of seed lots selected on the basis of one character alone may some time not give the desired level of superiority. Seed source selection should be made on the basis of multi traits consideration as reported by GINWAL *et al.* (1996) and VAKSHASYA *et al.* (1992).

Seeds of *A. chinensis* mature during December to March in its natural range of distribution, when the climate is cold (more colder at higher altitudes as compared to lower where it is warm during the day). This type of climate may not be congenial for seed development at higher elevations, and therefore, in this case damaged seed incidence was slightly pronounced with increasing altitude, which is contradictory to earlier findings in other species (SAKLANI, 1999). In this case number of healthy seeds/pod was found higher in the provenances situated at lower altitudes of southern localities.

The existing positive and highly significant correlation between seed weight and altitude of seed source indicate a trend of increasing heavy seeds towards higher elevational sources. Furthermore, higher nursery germination was recorded in heavier seeds. However laboratory germination was non-effective to this variable. Most of the middle elevational provenances proved better germination in laboratory (at 25 °C) as well as in nursery. On an average shoot and root biomass was found maximum in lower elevational provenances as compared to that in middle and higher elevational provenances. Decreasing plant height, biomass production and number of root nodules/plant with increasing altitudes, clearly indicate that this species is most suitable for moderate (towards middle) altitudinal ranges, where it is adapted genetically and physiologically.

Among the studied variable greater variations were found in lower elevational sources for maximum traits as compared to higher elevational once where fewer (1–2) traits had significant variations. On the other hand laboratory and nursery germination were found most variable as compared to all the seedling growth traits. Higher values of broad sense heritabilities were estimated for almost all the growth traits but with lower genetic gain which was found higher for seed weight which indicate a considerable portion of genetic variation as additive, which suggests the possibility of rapid genetic improvement on growth characters at early stages through provenance and parent tree selection in *A. chinensis.* The characters, which showed greater genetic influence, can be directly screened/ selected for the improvement of this potential tree-crop.

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Identification of the origin of Portuguese Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco] provenances

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Summary

Douglas-fir was introduced to Portugal in the 19th century and the first plantations were established at the beginning of the 20th century. Since then, it has been planted in the mountainous areas of the centre and north of Portugal. The Portuguese Forestry Service has generally accepted that the establishment of younger plantations has been carried out mainly using seed from existing plantations. Unfortunately, the native North American sources of seeds used for establishment of the older plantations are unknown.

Isozyme analysis (seven loci) of megagametophyte tissue, from 10 Portuguese provenances sampled from across their introduced range (277 trees) and 17 native provenances, was used to investigate genetic variation: (i) among Portuguese Douglas-fir provenances; and (ii) between Portuguese and North American provenances of the 'coastal' variety, with the aim of identifying the putative source provenances for exotic Portuguese provenances. Among the Portuguese provenances, the expected heterozygosity (H_e) was 0.254, which was similar to previous investigations which sampled a wider range of the natural distribution. Therefore, these results reflect a considerable level of genetic diversity within Portuguese Douglas-fir provenances and may be evidence that the Portuguese material has come from more than one source.

UPGMA clustering of Nei's genetic distances for Portuguese and native provenances showed the majority of Portuguese Douglas-fir provenances fell into a single, poorly resolved group together with provenances from across the native range of Douglas-fir. Whether all the Portuguese provenances in this group are the product of a single introduction from the native range and then separate establishment in different parts of Portugal

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